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Tward

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[54] **CYCLING JOULE THOMSON REFRIGERATOR**

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[52] **U.S. Cl.** .... **62/514 R;** 62/48; 337/14
[58] **Field of Search** .... 62/48, 514 R, 514 JT, 62/480, 490; 337/114

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,611,740	10/1971	Giger	62/514 R
4,048,814	9/1977	Quack	62/514 R
4,111,002	9/1978	Van Mal et al.	62/514 R
4,161,211	7/1979	Duffy et al.	62/48
4,178,987	12/1979	Bowman et al.	62/48

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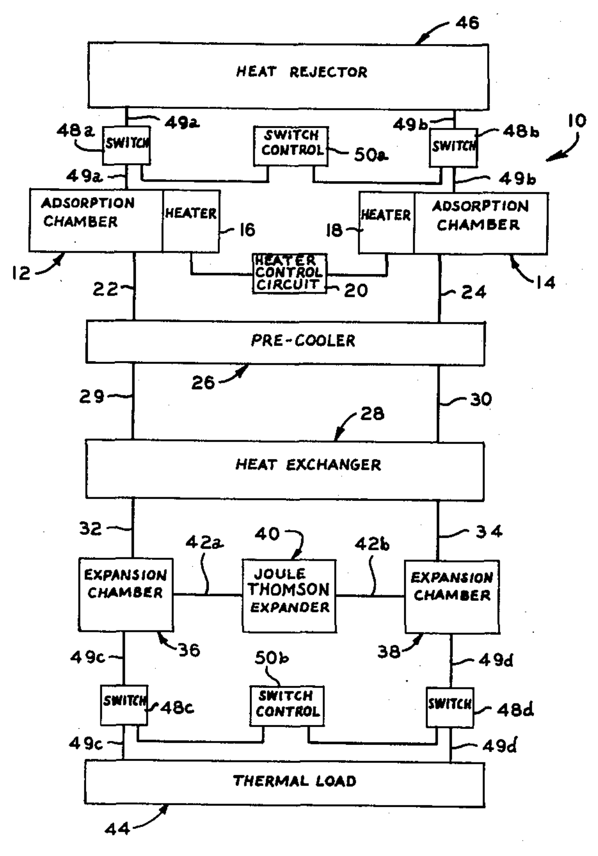
[57] **ABSTRACT**

A symmetrical adsorption pump/compressor system having a pair of mirror image legs and a Joule Thomson expander **40,** or valve, interposed between the legs thereof for providing a new, efficient refrigeration cycle. The system further includes a plurality of gas operational heat switches **48***a,* **48***b,* **48***c,* and **48***d* adapted selectively to transfer thereto heat from a thermal load **44** and to transfer or discharge heat therefrom through a heat projector **46,** such as a radiator or the like. The heat switches comprise gas pressurizable chambers adapted for alternate pressurization in response to adsorption and desorption of a pressurizing gas confined therein.

6 Claims, 3 Drawing Figures



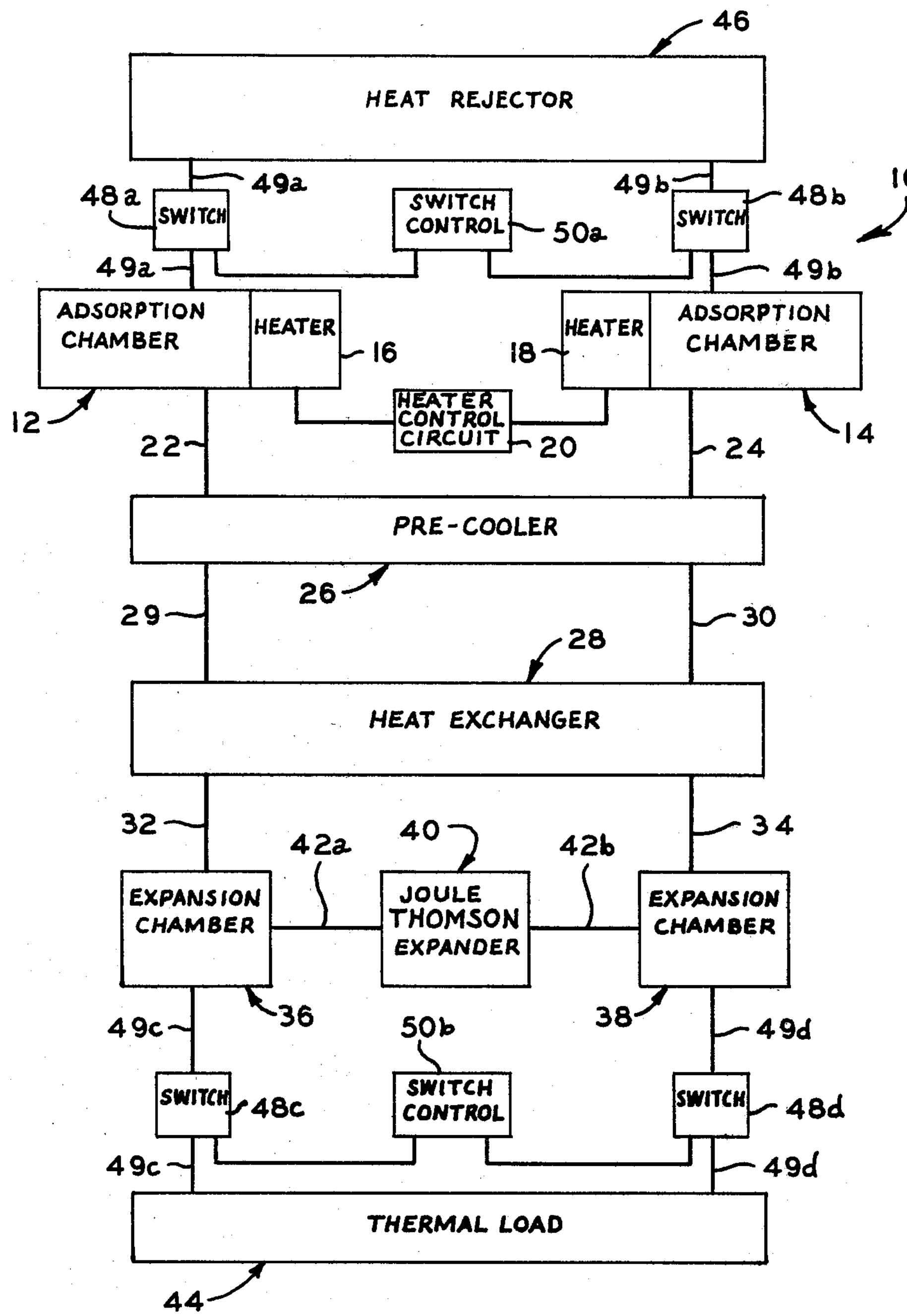

46
HEAT REJECTOR
49a
48a
SWITCH
SWITCH CONTROL
50a
49b
SWITCH
48b
10
49a
49b
ADSORPTION CHAMBER
HEATER
16
18
HEATER
ADSORPTION CHAMBER
12
HEATER CONTROL CIRCUIT
20
14
22
24
PRE-COOLER
26
29
30
28
HEAT EXCHANGER
32
34
40
42a
42b
EXPANSION CHAMBER
JOULE THOMSON EXPANDER
EXPANSION CHAMBER
36
38
49c
50b
49d
SWITCH
48c
SWITCH CONTROL
SWITCH
48d
49c
49d
THERMAL LOAD
44

Fig. 1

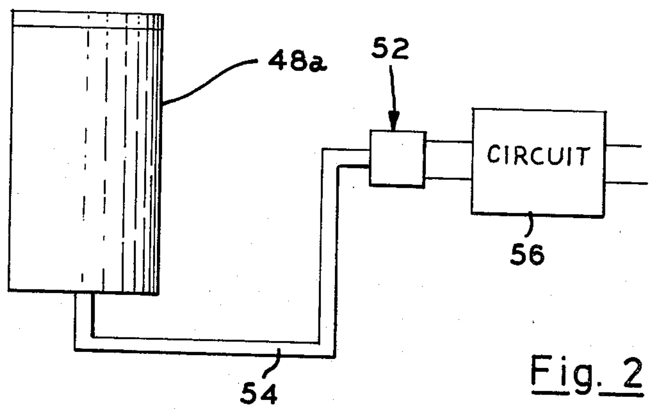

48a
52
CIRCUIT
56
54

Fig. 2

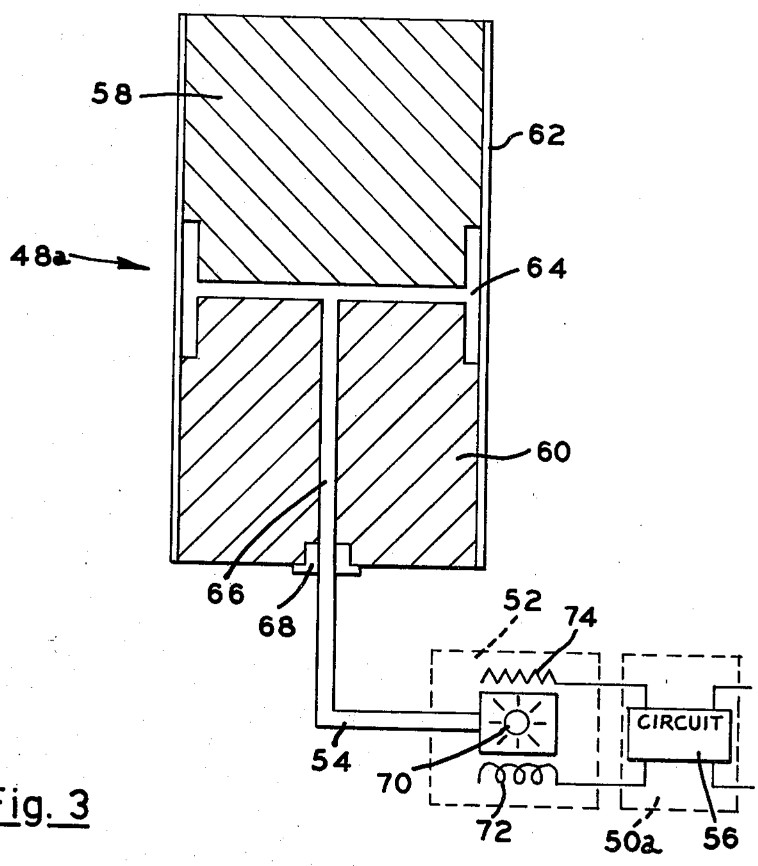

58
62
48a
64
60
66
68
52
74
CIRCUIT
54
70
72
50a
56

Fig. 3

CYCLING JOULE THOMSON REFRIGERATOR

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA Contract and is subject to the provisions of Section 305 of the National Aeronautics & Space Act of 1958, Public Law 85-568 (72 STAT 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

The invention generally relates to adsorption refrigeration systems and more particularly to a new symmetrical adsorption pump/compressor system combined with a Joule Thomson valve for providing a new, efficient refrigeration cycle.

DESCRIPTION OF THE PRIOR ART

Heretofore, long-life reliable refrigerators of relatively low mass and bulk generally have been unavailable. The lack of such refrigerators particularly has been recognized in the aerospace industry which requires reliability exceeding that of the mechanical refrigerators heretofore available in the marketplace. The lack of sufficient reliability results, at least in part, from the fact that mechanical refrigerators tend to fail because of an inherent degradation of moving parts and associated seals occuring during missions of long durations. Additionally, it generally is accepted that mechanical refrigerators tend to be of excessive bulk and mass and thus generally are found to be undesirable in many phases of the aerospace industry. Adsorption refrigerators, of course, are notoriously old.

In view of the foregoing, it should now be apparent that there currently exists a need for a serviceable and dependable system having high heat dissipating capabilities and yet adaptable for miniaturization for use in systems of types often encountered in the aerospace industry.

It is therefore the general purpose of the instant invention to provide an improved refrigeration system comprising a new symmetrical adsorption pump/compressor combined with a Joule Thomson valve through a use of which a refrigeration cycle of enhanced reliability is realized.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved refrigeration system characterized by increased reliability and with attendant reduction in mass and bulk.

It is another object to provide in an adsorption refrigeration system wherein a gas reversely is caused to flow through the system for thus enhancing the cooling capabilities thereof.

It is another object to provide a symmetrical adsorption refrigeration system with a Joule Thomson valve to provide a new refrigeration cycle characterized by an enhanced efficiency.

It is another object to provide an improved adsorption system the operation of which is controlled through a plurality of heat switches, such as gas heat switches.

Another object is to provide an improved adsorption refrigeration system which is particularly useful in the aerospace industry, although not necessarily restricted in use thereto since the refrigeration system may be

employed in a terrestial environment wherein a high degree of efficiency is required, without attendant weight and bulk penalties being imposed.

It is another object to provide an improved gas heat switch having a capability for accommodating selective switching operations.

These together with other objects and advantages are achieved through a combination of a Joule Thomson valve with a symmetrical adsorption pump-compressor and a plurality of gas heat switches adapted selectively to apply heat from a thermal load and to discharge heat through a heat rejector, such as a radiator or the like, as will become more readily apparent by reference to the following description and claims in light of the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a system embodying the principles of the instant invention.

FIG. **2** is a schematic view depicting a heat switch coupled with a control circuit, as is employed in the system shown in FIG. **1**.

FIG. **3** is a vertically sectioned, partially schematic view depicting the heat switch shown in FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings with more particularity, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. **1** a system characterized by a symmetrical adsorption pump/compressor system, hereinafter referred to as an adsorption refrigeration system, generally designated **10**, embodying the principles of the instant invention.

As hereinbefore mentioned, adsorption refrigeration systems are notoriously old. Further, the specific structure required and the modes of operations employed in successful operation of various system components as found in a conventional adsorption refrigeration system, generally are believed to be well known. Therefore, since the details of the conventional components form no part of the claimed invention, a detailed description of each of the components depicted in the drawings is neither deemed necessary nor desirable.

It suffices to understand that the system **10** includes a first adsorption chamber generally designated **12** and a second adsorption chamber, generally designated **14**. In practice, each of the adsorption chambers is of known design and includes therein a suitable adsorbant, not shown. Suitable adsorbants, however, include Zeolite, charcoal, and metal hydrides utilized in a manner fully understood by those familiar with adsorption refrigerators.

It is to be understood that the system **10** is charged with a body of gas. Such a gas is characterized by a relatively high cooling capacity when expanded and is compatible with the particular adsorbant employed. One gas found suitable for use with the aforementioned adsorbants is helium. However, other gases may be employed equally as well, all without departing from the scope and spirit of the instant invention.

As shown, a pair of heater units, designated **16** and **18**, are provided for selectively heating the adsorption chambers **12** and **14**, respectively. For purposes of providing for a complete understanding of the instant in-

vention, it may be assumed that the heaters **16** and **18** comprise resistance heaters.

Also, for the sake of providing for a complete understanding of the instant invention, there is depicted a heater control circuit **20** connected with each of the heaters **16** and **18** for purposes of controlling the operations thereof. However, it is important to note that heaters of other types can be employed equally as well. For example, depending upon prevailing temperatures and heat transfer capability required in a given environment for the system, the heaters **16** and **18** may constitute no more than thermal bridges coupled to sources of heat found to exist in the environment in which the system **10** is employed.

The system **10** also includes fluid conduits **22** and **24**. These conduits are connected at the output side of the adsorption chambers **12** and **14** and serve to commonly connect thereto a pre-cooler, generally designated **26**. The pre-cooler **26** is of any suitable design. Where so desired, the pre-cooler **26** may comprise a simple heat exchanger, such as a radiator or a refrigerator, driven by a suitable auxiliary system, not shown. Additionally, like the heaters **16** and **18**, the pre-cooler **26** may constitute no more than a thermal bridge having a capability for delivering to the system's environment, heat extracted from the gas as it is caused to flow therethrough.

At the output side of the pre-cooler **26**, there is provided a heat exchanger **28**, also of known design. The design and function of the heat exchanger **28** is similar to the design and function of such devices found in conventional adsorption refrigeration systems.

Briefly, the heat exchanger **28** is coupled at the output side of the pre-cooler **26**, through conduits **29** and **30**, which permit gases flowing through the heat exchanger **28** to flow in cyclically reversing directions, as will hereinafter become more readily understood. The purpose for accommodating gas flow through the heat exchanger is to transfer heat from the gas for further cooling the gas as it is caused alternately to exit the adsorption chambers **12** and **14**.

Connected to the output side of the heat exchanger **28**, via conduits **32** and **34**, there is a pair of expansion chambers, generally designated **36** and **38**. The expansion chambers **36** and **38** also are of a design well known by those familiar with adsorption refrigeration systems. Therefore, a detailed description of these system components also is omitted in the interest of brevity. However, it is to be understood that while the expansion chambers **36** and **38**, as herein employed, may be considered to comprise "free" expansion chambers, where so desired, conventional Joule Thomson valves may be employed for accommodating an expansion of the gas as it alternately is expelled into the expansion chambers **36** and **38**.

Finally, interposed between the expansion chambers **36** and **38** there is a Joule Thomson expander, generally designated **40**. The Joule Thomson expander, as employed, also is of conventional design and is characterized by a capability of accommodating a rapid expansion of gases, such as the capability which characterizes a conventional Joule Thomson valve. As shown, the Joule Thomson expander **40** is interposed between and connected with both of the expansion chambers **36** and **38** through conduits, designated **42*a*** and **42*b***. As also will hereinafter be more readily apparent, a selected gas is cyclically caused to flow reversely through the expander **40** for purposes of further cooling the gas, prior to its alternate delivery, to a "downstream" expansion chamber, **36** or **38**, as is dictated by the direction in which the gas is caused to flow through the expander **40**.

At this juncture, it is important to note that the system **10** is interposed between a thermal load, designated **44**, and a heat rejector, generally designated **46**. The thermal load, of course, is, in operation, cooled by the system **10**, while the heat rejector **46** simply serves as a heat discharge component for the elimination of thermal energy. In practice, the thermal load **44** may comprise any type of load found aboard a vehicle, such as electronic equipment found aboard space craft, while the heat rejector **46** comprises no more than a plate exposed to ambient temperatures.

It is at this juncture, important to note that both the thermal load **44** and the heat rejector **46** are connected to the system **10** via selectively operable gas heat switches, designated **48*a***, **48*b***, **48*c*** and **48*d***, interposed in thermal conductors **49*a***, **49*b***, **49*c***, and **49*d***. Each of the heat switches **48*a*** through **48*d***, in turn, are controlled through switch control circuits or components, designated **50*a*** and **50*b***.

Since the heat switches **48*a*** through **48*d*** are of a similar design, a detailed description of a single one of the switches is deemed adequate for a complete understanding of the instant invention. Therefore, with reference to FIG. **2**, it can be seen that the switch **48*a*** comprises a substantially hermetically sealed unit connected with a further adsorption chamber **52** through a suitable conduit **54**. The operation of adsorption chamber **52** is, in turn, controlled through an electrical control circuit **56**. This circuit is of any suitable design, but as shown, FIG. **3**, control of this circuit is obtained through conventional circuitry, designated **50*a***. Since the control circuit **56**, as well as the control circuit **50*a*** therefor, forms no part of the invention herein claimed, a more detailed description thereof is omitted in the interest of brevity.

Referring now to FIG. **3**, however, it can be seen that the heat switch **48*a*** includes a first thermal conductive member **58** and a second thermal conductive member **60**. The members **58** and **60** are mutually spaced and are fabricated from any one of a myriad of metals, or similar materials, comprising good thermal conductors. The wall of the switch, designated **62**, is fabricated from a material comprising a relatively poor thermal conductor, or thermal insulating material. A suitable material, such as thin glass, has been used with acceptable success. As shown, the wall **62** is of a cylindrical configuration while the members **58** and **60** conform to cylindrical plugs received in the opposite ends of the wall **62**. Defined between the members **58** and **60** there is a pressure chamber **64**. In practice, the thickness of the walls **62** and the axial dimension of the chamber **64** are minimized for thereby enhancing the system's efficiency.

As is well known, a chamber charged with a pressurized thermal conductive gas, such as helium, has a capability of conducting a thermal current from a first body to a relatively cooler second body. Accordingly, it is to be understood that an interruptable thermal path may be established between the members **58** and **60** simply by causing the chamber **64** to undergo pressurization, for thereby establishing a current path between the members **58** and **60**, and subsequently to undergo evacuation for purposes of interrupting the thus established thermal path between the members. Thus a "switching" function is achieved.

As is also well-known, it is possible to cool an adsorbant for thus causing the adsorbant to adsorb a quantity of gas and later give up the gas in the presence of heat.

Hence, in order to achieve the desired pressurization and subsequent evacuation of the pressure chamber **64**, the adsorption chamber **52** is connected to communicate with the pressure chamber **64** via a bore **66**. As shown, the bore **66** is extended axially through the member **60**. Where so desired, the conduit **54** is axially mated with the bore **66**. Such is achieved in any suitable manner, such as through a use of a suitable coupling **68** received within one end of the bore **66**. Since the particular manner in which the conduit **54** is coupled with the bore **66** forms no part of the claimed invention, a detailed description thereof is omitted in the interest of brevity.

It is important to note, however, that within the adsorption chamber **52** there is disposed a quantity of an adsorbant material, herein referred to as an adsorber, designated **70**. The adsorber may be fabricated from Zeolite, charcoal, or a metal hydride. Additionally, it is to be understood that the chambers **52** and **64** are charged with a quantity of compatable, thermally conductive gas which is suited for adsorption by the particular adsorbant employed. Helium gas, not shown, and a Zeolite adsorbant may be employed satisfactorily as a suitable gas/adsorber combination.

At this juncture, it is noted that within the chamber **52** there is provided a device **72** for cooling the adsorber. While the device **72** comprises a cooling coil, as depicted, the cooling coil may be omitted in those instances where a thermal leak is sufficient for transferring a suitable flow of thermal energy from the adsorber **70** to an ambient environment.

Additionally, a heating device, such as a resistance heater **74**, as shown, comprises a device suitable for heating the adsorber **70**. Here again, it is possible to eliminate the resistance heater **74** in those instances where thermal energy may be delivered through other means to the adsorber **70** in sufficient quantities.

In practice, one manner in which the system is caused to function quite satisfactorily in a terrestial environment is to connect a thermal conductor between the adsorption chamber **52** and a source of low temperature which is sufficient to conduct heat from the adsorption chamber at a rate adequate for causing the adsorber **70** to adsorb the gas once the heater **74** is switched off. However, for the sake of providing for a complete understanding of the instant invention, it is to be understood that where so desired, the control circuit **56** also includes conventional circuit components having a capability of switching the adsorption chamber **52** between a desorbing, or system pressurizing mode, and an adsorbing, or system evacuating mode, for purposes of varying the thermal conductivity of the chamber **64**.

In view of the foregoing, it should now be apparent that once the adsorber **70** is cooled to a low temperature, the body of gas contained in the chambers **64** and **52** is adsorbed by the adsorber **70**. Consequently, there thus is established a sparsity of gas molecules in the chamber **64** so that the thermal conductivity of the chamber **64** is greatly reduced. However, upon a heating of the adsorber **70**, the gas previously adsorbed is desorbed for again pressurizing the chambers **52** and **64** whereby the molecular population therein is increased. Thus, the thermal conductivity of the chamber **64** is greatly enhanced.

Hence, it should now be apparent that by controlling the heating and the cooling of the adsorber **70**, through the heating element **74** and the cooling coil **72**, or by other means, the thermal conductivity of the chamber **64** is varied and thus the thermal switch is switched between open and closed modes.

OPERATION

It is believed that in view of the foregoing description of the invention, the operation of the system **10** will readily by understood, however, in the interest of assuring a complete understanding of the invention and its operation, it will briefly be reviewed at this point.

With the adsorption refrigeration system **10** interconnected between the thermal load **44** and a heat rejector **46**, the system is prepared for operation. A cycle of operation is hereinafter more fully described.

Initially, it is understood that when the switches **48*a*** and **48*c*** are open, the switches **48*b*** and **48*d*** will be closed. Opening and closing of the heat switches **48*a*** through **48*d*** is achieved by varying the temperature for the adsorber **70** within the adsorption chamber **52** of the switch control devices **50*a*** and **50*b***. Assuming that the heater **16** initially is energized through a suitable activation by the heater control circuit **20**, and further assuming that upon energization of the heater **16** the adsorbant contained within the adsorption chamber **12**, not shown, is heated for thus causing the previously adsorbed gas contained therein to be discharged from the adsorption chamber, via the conduit **22**. As the gas passes from the adsorption chamber **12** it is caused to pass through the pre-cooler **26** at which a pre-cooling of the gas occurs. The pre-cooled gas now continues to flow through the conduit **29** to the heat exchanger **28** and thence to the expansion chamber **36**, via the conduit **32**. Of course, the gas gives up heat in the heat exchanger **28** and undergoes further cooling at the expansion chamber **36**. However, the gas exits the expansion chamber **36**, via the conduit **42*a***, and is further expanded at the Joule Thomson expander **40** for a final cooling. Thereafter, the finally cooled gas is delivered to the expansion chamber **38**, via the conduit **42*b***. However, at this point, the switch control **50*b*** is operatively maintaining the switch **48*d*** interposed between the thermal load **44** and the chamber **38** in a switch-closed condition. Consequently, a thermal path for heat is established from the thermal load **44** to the expansion chamber **38** via the heat switch **48*d***. The gas flowing from the expander **40** to the expansion chamber **38** is permitted to pick up heat, derived from the thermal load **44**, and continues to flow toward the absorption chamber **14**, via the conduit **34**, the heat exchanger **28**, the conduit **30** and the pre-cooler **26**.

As the gas thus heated in the expansion chamber **38** is caused to pass through the heat exchanger **28**, additional heat is picked up from the gas passing therethrough from the pre-cooler **26**.

As the thus heated gas continues to flow from the heat exchanger **28**, toward the adsorption chamber **14**, it courses through the conduit **30** and thence to the pre-cooler **26**, the conduit **24** and then to the adsorption chamber **14**.

At this juncture, it is important to note that the heat switch **48*b*** is maintained in a switch-closed condition by the switch control **50*a*** for thus permitting heat to be transmitted from the adsorption chamber **14** to the heat rejector **46**, via the heat switch **48*b*** and the thermal conductor **49*b***. Thermal energy thus is conducted from

the adsorption chamber **14** to the heat rejector **46** via the heat switch **48*b*** and the thermal conductor **49*b***.

Of course, the heater **18** remains in a switch-off condition while the adsorbant confined therein serves to adsorb the body of gas, in response to a cooling of the adsorbant, as the thermal energy is transferred to the heat rejector **46** and thence to the ambient environment.

Once the body of gas within the system **10** is adsorbed within the adsorption chamber **14**, the second half of the cycle of operation is initiated simply by opening the heat switches **48*b*** and **48*d*** while closing the heat switches **48*a*** and **48*c***, employing the switch controls **50*a*** and **50*b*** in a suitable manner.

Additionally, the heater **16** is de-energized while the heater **18** is energized for purposes of accommodating a cooling of the adsorbant within the adsorption chamber **12** and a heating of the adsorbant within the adsorption chamber **14**. As the adsorbant within the adsorption chamber **14** is heated, desorption of the gas is initiated, causing the gas to flow in a direction reverse to that described with respect to the first half-cycle of operation for the system **10**.

Consequently, it will be appreciated that gas now flows from the chamber **14** through the pre-cooler **26**, the heat exchanger **28**, the expansion chamber **38** and is finally cooled at the Joule Thomson expander **40**, prior to its delivery to the expansion chamber **36**. The expansion chamber **36** now is being heated in response to the thermal load **44** being applied thereto via the thermal conduits **49*c*** and the closed switch **48*c***. The heated gas now exits the expansion chamber **36** and continues to flow to the adsorption chamber **12**, via the conduits **32**, **29**, and **22**, while passing through the heat exchanger **28** and the pre-cooler **26**. The thermal energy of the gas is now delivered to the heat rejector **46**, via the thermal conduits **49*a*** and the gas heat switch **48*a***. In response to a delivery of the thermal energy from the gas, the adsorbant within the chamber **12** cools for thus permitting the gas to be adsorbed. Thus the cycle of operation of the system is complete.

As hereinbefore described, the "opening" and "closing" of the gas heat switches **48*a*** through **48*d*** are controlled simply by controlling the temperature of the adsorber **70**, for selectively pressurizing and de-pressurizing the chamber **64**. Control of the temperature of the adsorber **70** is selectively controlled by imposing control over control circuit **56** utilizing the controller **50*a*** and **50*b***.

In view of the foregoing, it is believed to be readily apparent that the invention hereinbefore described provides a practical and economic solution to the problems of enhancing the longevity, increasing efficiency, and reduing the mass and bulk of refrigeration systems. It is contemplated that the invention as hereinbefore described ultimately will find utility in micro-electronic industries.

What is claimed is:

1. In an adsorption refrigeration system the improvement comprising:

A. first system means for alternately adsorbing and desorbing a system pressurizing gas including an adsorption chamber;

B. second system means for alternately adsorbing and desorbing said system pressurizing gas including an adsorption chamber;

C. circuit means interconnecting said first and second system means for sequentially directing a cyclically reversing flow of said system pressurizing gas between said first and said second system means including a Joule Thomson expander for cooling the gas, said circuit means further including a first and a second expansion chamber interconnected in communicating relation through said Joule Thomson expander, and means connecting said expansion chambers in mutually independent communicating relation with said adsorption chambers;

D. a first pair of heat switches connected to said first and second system means for alternately connecting a heat load to said first and second expansion chambers;

E. a second pair of heat switches connected to said first and second systems means for alternately connecting a heat rejector to said adsorption chambers; and

F. means for alternately closing the heat switches of each pair of heat switches.

2. An improvement as defined in claim **1** wherein each heat switch comprises:

A. a pair of thermal conductors disposed in mutually spaced relation for defining therebetween a pressure chamber, a further adsorption chamber including an adsorbant and a quantity of gas connected in communicating relation with said pressure chamber, and said means for alternately closing the heat switches including means for alternately initiating an adsorbing and desorbing of the gas included in said further adsorption chamber for thereby pressurizing and depressurizing said pressure chamber, whereby said heat switch alternately is rendered thermally conductive and thermally insulative.

3. In a symmetrical adsorption refrigeration system, the improvement comprising:

A. a first system means including a first adsorption chamber for alternately adsorbing and desorbing therein a system pressurizing gas;

B. a second system means including a second adsorption chamber for alternately adsorbing and desorbing therein said system pressurizing gas;

C. system control means for sequentially pressurizing said first and second system means for initiating desorption of the system gas in the first adsorption chamber while simultaneously initiating adsorption of the system pressurizing gas in the second adsorption chamber, and subsequently initiating desorption of the system pressurizing gas in the second adsorption chamber while simultaneously initiating adsorption of the system pressurizing gas in the first adsorption chamber;

D. circuit means including a Joule Thomson expander interconnected with said first and second system means for conducting a reversing flow of said system pressurizing gas between said first and said second adsorption chambers in response to a sequential pressurization of said first and second system means; and

E. said system control means includes a first pair of gas heat switches for alternately connecting a heat load to said first and second system means, and a second pair of gas heat switches for alternately connecting heat rejection means to said first and second system means.

4. The improvement of claim **3** where each gas heat switch comprises:

A. a pair of mutually spaced thermal conductors having a pressurizable chamber defined therebetween, and means for alternately delivering a pressurizing gas to said pressurizable chamber including a further adsorption chamber containing an adsorbant connected in communication therewith and a quantity of pres-

surizing gas, and means for selectively initiating adsorption and desorption of said pressurizing gas.

5. The improvement as defined in claim 4 further comprising:

A. a heat exchanger commonly connected to the adsorption chambers of said first and second system means; and

B. means defining a heat input to said first and second system means comprising a pair of expansion chambers commonly connected in communication with said heat exchanger and said Joule Thomson expander.

6. A symmetrical adsorption refrigeration system comprising:

A. first system means and second system means and a body of adsorbable gas for alternately and reversely pressurizing said first and second system means, each of said system means comprising a thermally responsive adsorption chamber containing an adsorber for alternately adsorbing and desorbing said body of gas, and temperature control means connected with said adsorption chambers for thermally initiating adsorption and desorption of said body of gas;

B. circuit means defining a flow path extended between said adsorption chambers for conveying a cyclically reversing flow of said body of gas to and away from each of said adsorption chambers including a precooler connected in communication with each of said adsorption chambers for cooling said body of gas as it is caused to flow away from said adsorption chambers, a heat exchanger commonly connected to said adsorption chambers for further cooling said body of gas as it flows away from said adsorption chambers, and a pair of expansion chambers connected in communication with said adsorption chambers via said heat exchanger and said pre-cooler, and means including a Joule Thomson expander interconnecting said expansion chambers in mutual communication as it flows between said expansion chambers;

C. means including a first pair of normally open gas heat switches adapted alternately to close for cyclically connecting to each of said expansion chambers a heat load;

D. means including a second pair of normally open gas heat switches adapted alternately to close for cyclically connecting to each of said adsorption chambers, heat rejection means, each of said heat switches being characterized by a chamber pressurizable to define a thermal path therethrough; and

E. heat switch control means connected to each of said heat switches, for varying the thermal conductivity thereof, said heat switch control means being characterized by a further adsorption chamber having a further adsorber and a further body of gas contained therein, said control means being connected in communicating relation with a gas pressurization chamber of said first and second pair of heat switches and means for selectively varying the temperature of said further adsorption chambers.

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